GEWEX Americas Prediction Project (GAPP)

FY2004 Annual Report on

Diagnostic and Predictive Studies of Land Surface Hydrology Employing New Data Sets
(GC04-039)

Project period: May 2004 – April 2007

Report period: May 2004 – April 2005

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1. Introduction

Overall objectives of this project are to improve our understanding and modeling of land memory processes, land surface energy and hydrological cycles, and the integration of predictability into prediction systems. The ultimate goal is to improve our capability to make more reliable monthly to seasonal predictions of air temperature, precipitation and land surface hydrological variables. The main focus of this project is to use the existing 4 land surface datasets (two 50+ Year NLDAS retrospective runs from Noah and VIC land surface models, NCEP North America Regional Reanalysis (NARR), and CPC ½ degree global soil moisture dataset) to identify and quantify land-atmosphere interaction and the impacts of land surface processes on the North America warm season precipitation. Some important scientific issues and GAPP priorities will be addressed here, specifically:

1). A three-way comparison NARR <-> retro-Noah <-> retro-VIC over common periods and areas, especially focused on the land surface hydrology processes.

2). An in-depth study of the 1948-1998 retro-Noah and 1948-present CPC global soil moisture data sets, focused on the data validation, diagnostic, prediction and predictability issues, related to land memory processes.

3). Use new data sets to re-assess local and non-local impacts of the land surface processes.

2. Work accomplished during the period of May 2004 –April 2005)

One of the GAPP priorities is to test model calculated land surface energy and hydrological budget terms against all available observations and comprehensive reanalysis, such as the NARR. Some preliminary work has been done in the following areas:

- **Data validation & analysis of 51 year (1948-1998) US land surface hydrologic reanalysis**

In this part of the study, we displayed the significant surface elevation difference between the 1/8th degree NLDAS topography and NCEP-NCAR Reanalysis topography on 1/8th degree NLDAS grid, especially in western mountain areas, and orographic effects on the detailed structure in the forcing data (see Fig.1 and Fig.2). The simulated soil moisture annual cycle and interannual variability from retro-Noah are compared with the Illinois observations. The results (Fig.3, Fig.4 and Fig.5) show the improvement of simulated soil moisture not only in the annual cycle (which is poor in CPC leaky bucket model), but also in the interannual variability. The results and some new found problems also give some indication for future modeling improvement.

- **Comparison with North American Regional Reanalysis**

The inter-comparison between retro-Noah and NARR is perhaps the most interesting and constrained. Not only is the land surface model almost identical, but also the hourly precipitation input for the NARR (which was produced by us in conjunction with retro-Noah) and for retro-Noah over 1979-98 is the same. The early results (Fig.5 and Fig.6) reveal that the overall performance of retro-Noah is better than the NARR, when compared with Illinois observations. The reason for the difference has not been determined and more detailed analysis is needed.

- **Gravity satellite data and calculated soil moisture: A mutual validation**

Calculations of soil moisture are very hard to verify because of a lack of observations worldwide. Only in a few areas, such as Illinois in the US, do we have enough in situ data for an extended time. Until now satellite data, through radiation instruments, have measured surface water (like ponding, or the state of vegetation), but could not penetrate much into the ground. Since 2002 we have time varying gravity measurements by a satellite called GRACE. It was anticipated that continental soil moisture variation is among the strongest signals to be detected by GRACE. The first and second years of satellite data, after other known signals were removed have been compared to the calculated global CPC soil moisture data. The annual cycle in mass in calculated soil moisture matches the gravity measurement to a fair degree worldwide (Fig. 7 and Fig.8).

- **Land surface memory studies and their local and non-local impacts**

Using CPC global soil moisture data set (1948-present), we started a few statistical analyses (Fig.9 and Fig.10) to understand the temporal and spatial variability of land memory signals and to identify non-local impacts of soil moisture and the source of potential predictability from land memory.

3. Publications

Fan, Y. and H. van den Dool, 2004: The CPC global monthly soil moisture data set at ½ degree resolution for 1948-present. *J.Geophs.Res.,* 109, D10102, doi:10.1029/2003JD004345

Yun Fan, Huug M. van den Dool and Peitao Peng, 2004: Land Memory Study Using CPC's New Global

Soil Moisture Dataset from 1948-Present. Proceedings 29th Climate Diagnostics and Prediction Workshop, Madison, Wisconsin.

Fan, Y., H. van den Dool, D. Lohmann, and K. Mitchell, 2004: A 50+ Year US hydrological reanalysis of the Noah Land Data Assimilation System. (submitted to *J.Climate*)

K. Mitchell, M. Ek, Y. Lin, F. Mesinger, G. Dimego, P. Shafran, D. Jovic, W. Ebisuzaki, W. Shi, Y. Fan, J. Janowiak, J. Schaake, 2004: NECP Completes 25-Year North American Reanalysis: Precipitation Assimilation and Land Surface Are Two Hallmarks. GEWEX News, 14, May Issue, 9-12.

Huug van den Dool, Yun Fan, John Wahr and Sean Swenson, 2004: Gravity Satellite Data and Calculated Soil Moisture: A Mutual Validation (update). Proceedings 29th Climate Diagnostics and Prediction Workshop, Madison, Wisconsin.

4. Meeting & workshop

GAPP PIs meeting, 30-31 August, 2004, Boulder, Colorado.

   Presentation 1: Data validation & analysis of 51 year (1948-1998) US land surface

   hydrological reanalysis.

   Presentation 2: Gravity satellite data and calculated soil moisture: A mutual validation.

29th NOAA Climate Diagnostic and Prediction Workshop, 18-22 October, 2004, Madison, Wisconsin.

   Presentation 1: Land surface memory and its impacts

   Presentation 2: Gravity satellite data and calculated soil moisture: A mutual validation (update)
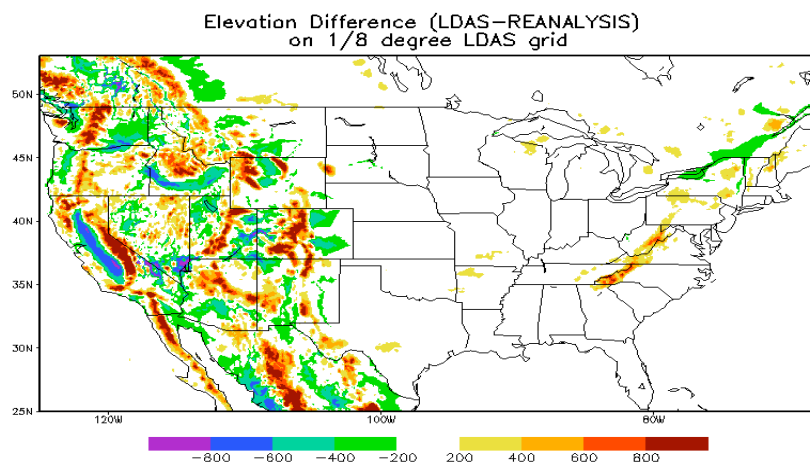
Fig.1 Significant surface elevation difference between the 1/8th degree
NLDAS topography and NCEP-NCAR Reanalysis topography on 1/8th
degree NLDAS grid. Unit is m.
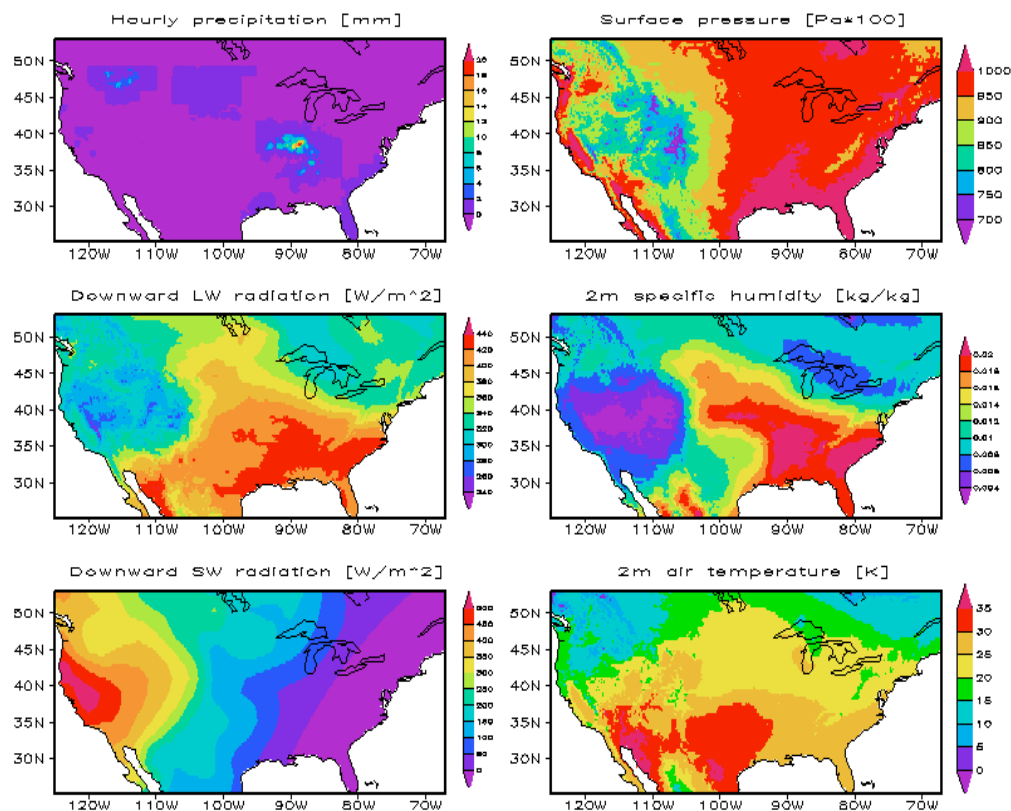
Fig.2 The hourly forcing fields (P, IR↓, S↓, p, q, T_a) at 01Z16Jul1993 are shown here as examples to display the characteristics of high spatial resolution & orographic effect on the NLDAS forcing data set.

a) Illinois Total Soil Moisture (mm) and Observed Precipitation (cm/day)
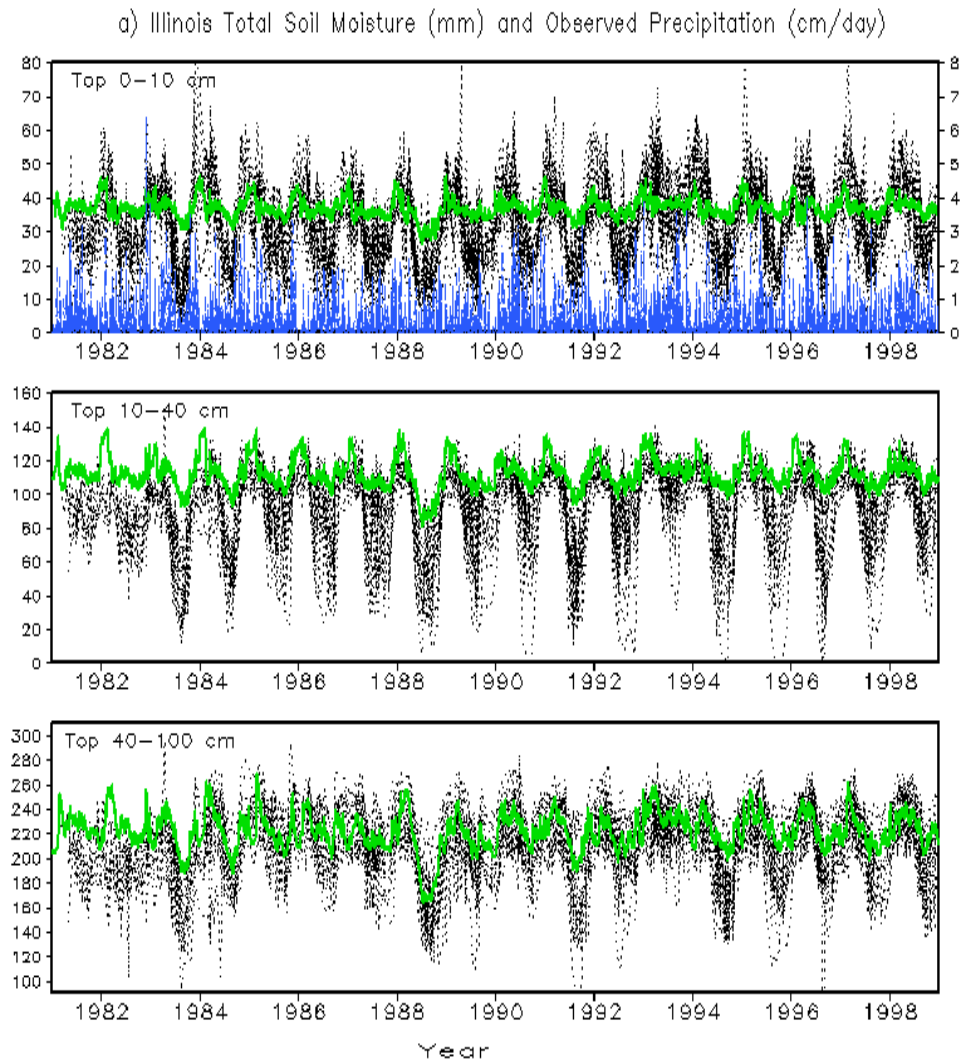
Fig.3 The time evolution of simulated daily total soil moisture (green solid) in the top three model layers and their relevant observations (black dots, all instantaneous data for all stations) in Illinois from 1981 to 1998, together with the observed daily precipitation (blue dash-dot, in top panel).
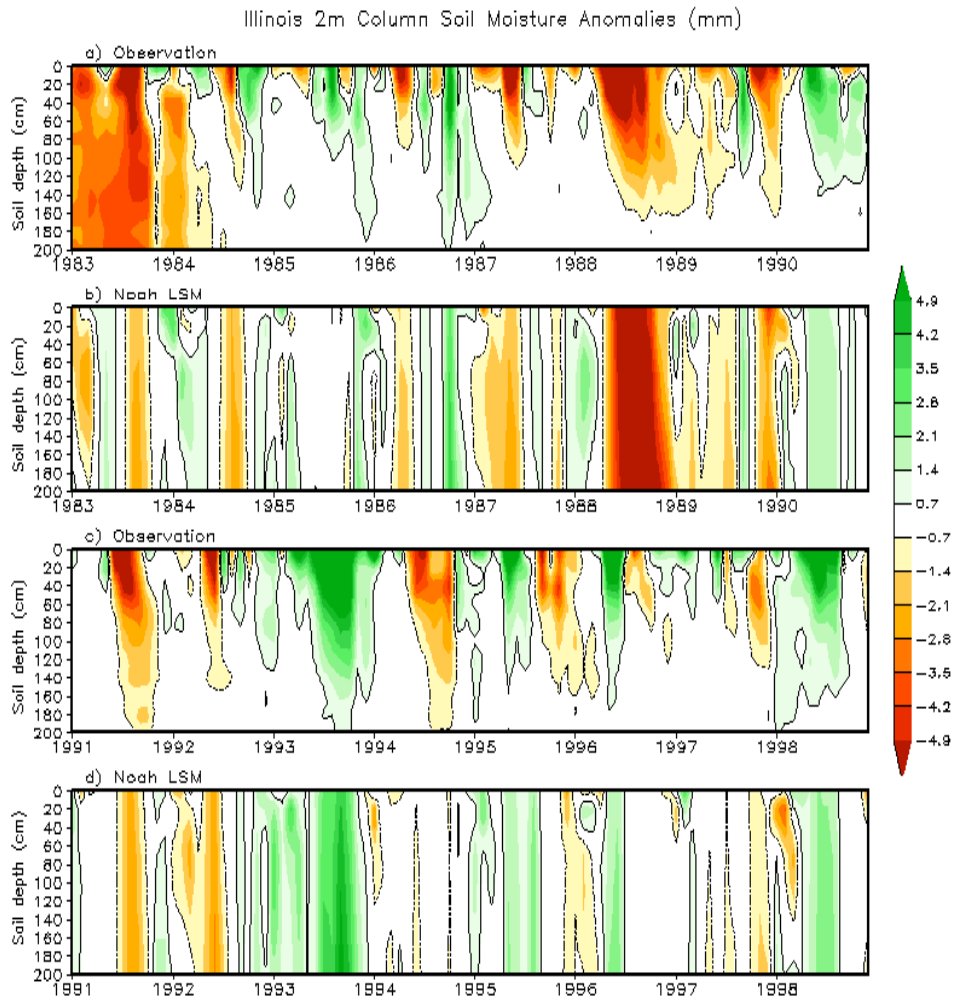
Fig.4 Observed and simulated vertical distribution of top 2 meter soil moisture anomalies averaged in Illinois from Jan. 1983 to Dec. 1998. The simulations are for 4 model layers: 0-10 cm, 10-40 cm, 40-100 cm and 100-200cm. The observations were made for 0-10 cm, 10-30 cm, 30-50 cm, 50-70 cm, 70-90 cm, 90-110 cm, 110-130cm, 130-150cm, 150-170cm, 170-190cm and 190-200cm. The units are mm of water per 10 cm of soil.
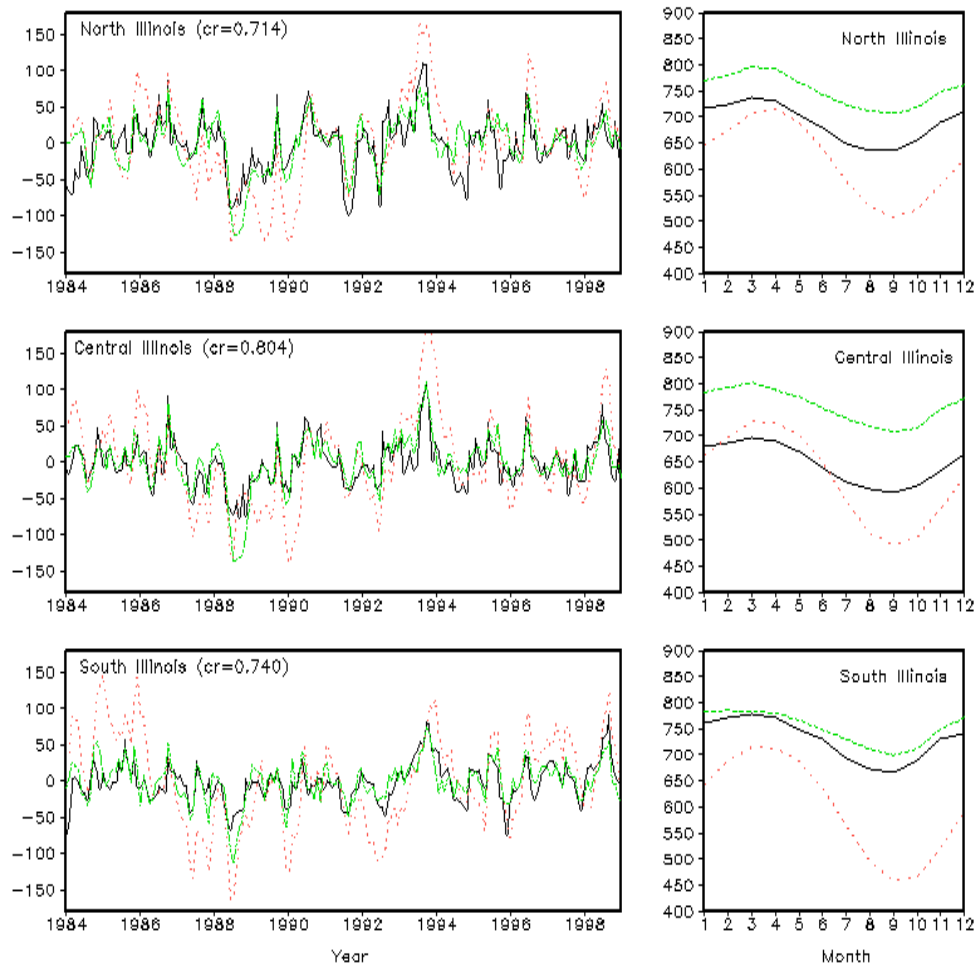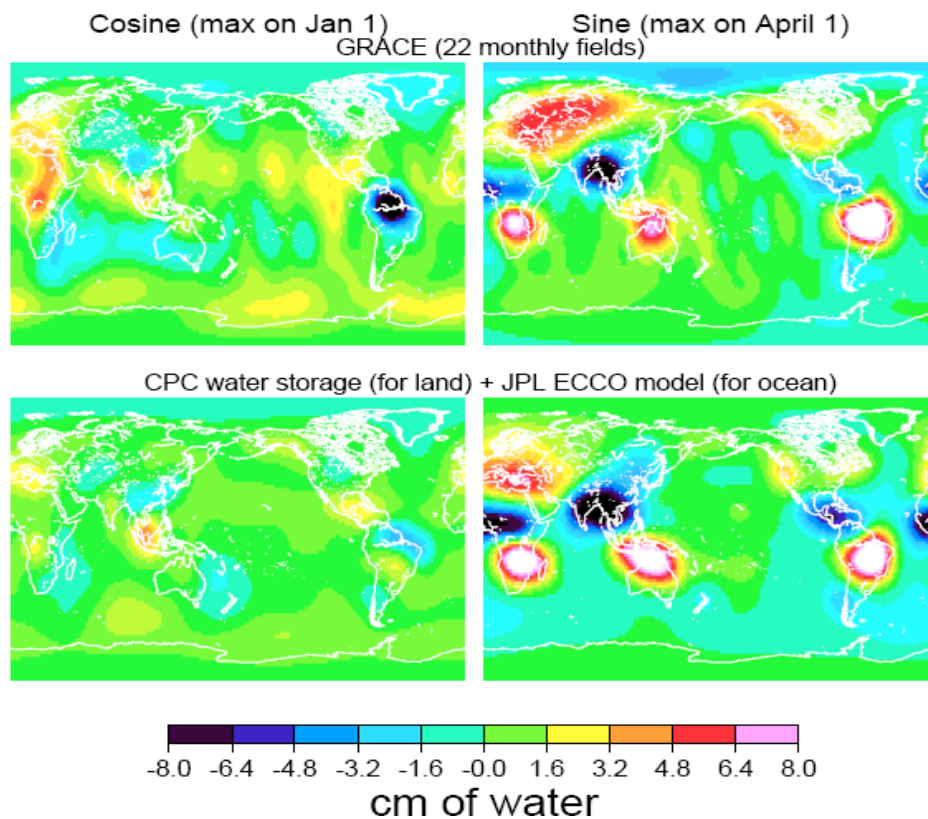
Fig.5 The annual cycle (right) & anomalies (left) of the observed & simulated 2 meter
column soil moisture in the north, central & south Illinois from 1984
to 1998. Black solid line is observation and green dash line is 51 year Noah NLDAS
Run and red dot line is the Regional Reanalysis.
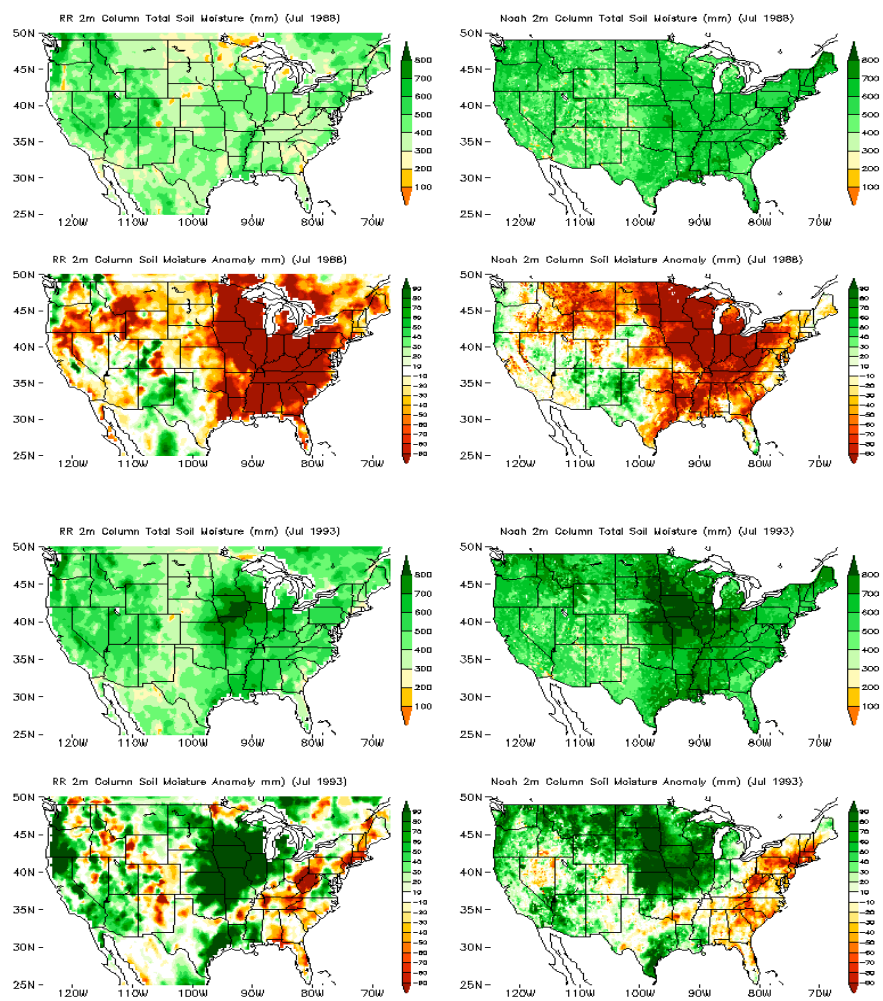
Fig.6 Simulated extreme land surface hydrologic events: 2m column soil
moisture anomalies for 1988 drought and 1993 flood.

Cosine (max on Jan 1)   Sine (max on April 1)
GRACE (22 monthly fields)

CPC water storage (for land) + JPL ECCO model (for ocean)

-8.0 -6.4 -4.8 -3.2 -1.6 -0.0 1.6 3.2 4.8 6.4 8.0
cm of water

Fig.7   Display of the sine and cosine terms of the annual variation in mass as seen by
GRACE and calculated by CPC's soil model for 2002-2004. Since soil moisture has its
extremes near March and September in nearly all climates the sine term dominates.
Broadly speaking GRACE and the model agree, both in pattern and in magnitude. Some
of the spill-over into the ocean has to do with de-convolution of spherical harmonics.,
although in the case of GRACE there may also be as-yet-unsolved problems with
removing all signals, other than soil moisture.
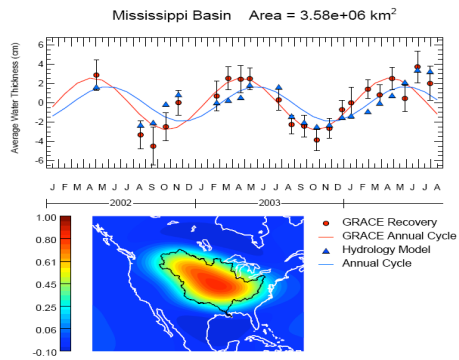
Fig.8a Comparison of GRACE and CPC soil model for the Mississippi Basin 2002-2004. The lower figure shows the approximation of this area's weighting function due to spherical harmonics. GRACE sees a somewhat stronger annual cycle in soil moisture and extremes that occur at least one month earlier.
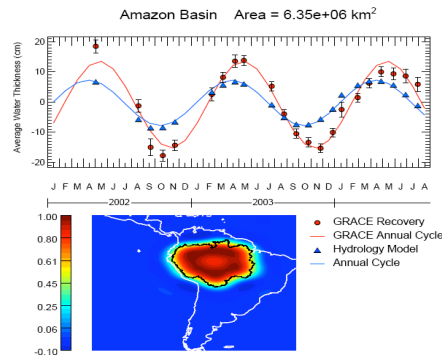
Fig.8b Same as Fig. 3, but now the Amazon Basin. Again the model has a weaker annual cycle, but the phase difference is less than in the Mississippi. In the Amazon the CPC soil model would benefit from greater than 76 cm holding capacity – this limitation
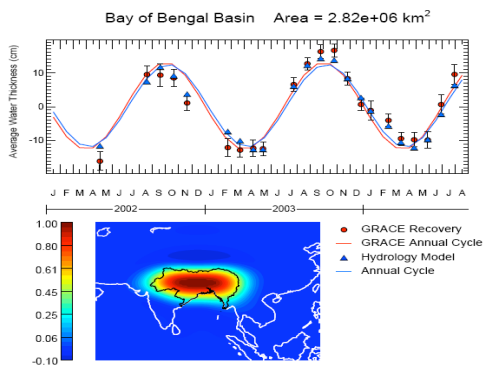
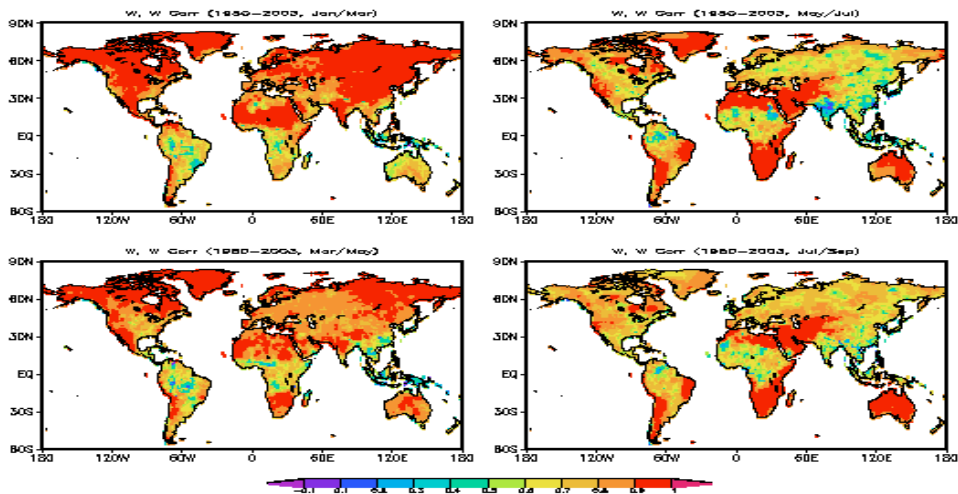Fig.8c As Fig. 3 and 4. In the Bengali Basin GRACE and CPC soil model are a perfect match.

Fig.9 Auto correlations of the global land surface soil moisture,which show that cold seasons and dry areas often have longer memory than those in warm seasons and wet areas.
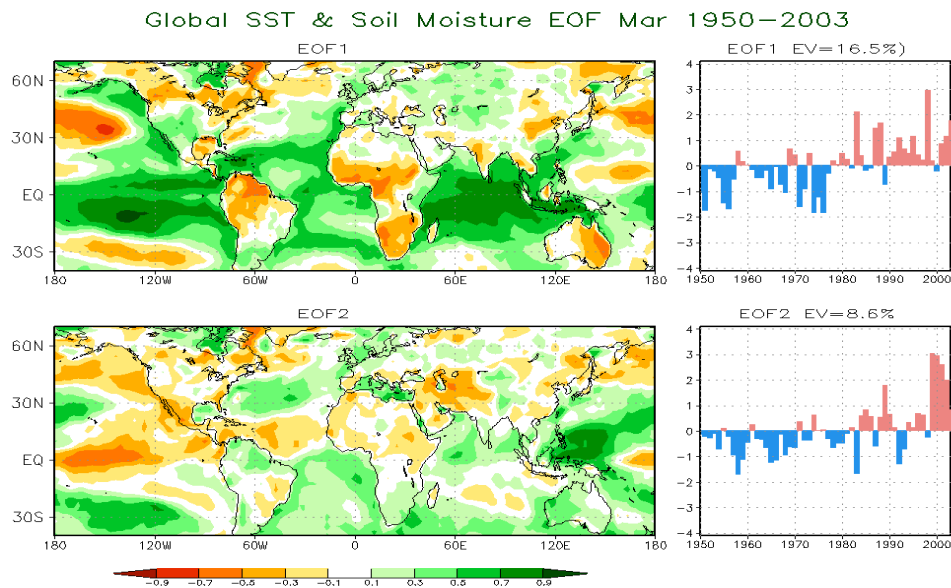

Fig.10 EOFs & PCs of the global lower boundary (normalized SST and soil moisture) for March 1950-2003. Both the El-Nino Southern Oscillation and long term trend modes are clearly seen in the leading EOFs & PCs of combined SST and soil moisture..